THE CRAYFISHES OF NEW JERSEY[1]

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The only study of the crayfishes of New Jersey was by Henry W. Fowler (1912) in the Annual Report of the New Jersey State Museum for 1911. Fowler's subject was the crustacea of the state and was too broad for a comprehensive treatment of the crayfishes. Little or no information is given on the distribution, life histories or ecology of the New Jersey species. The crayfishes of the adjacent states have been extensively studied by Ortmann (1906) in Pennsylvania and Crocker (1957) in New York. The Present study has the following aims: to identify and determine the distribution of the New Jersey crayfishes, to study the life histories and ecology of the species encountered, and to compare the morphology of the New Jersey crayfishes with those of adjacent regions and to investigate relationships, pathways of dispersion and barriers to migration.

METHODS AND MATERIALS

During the spring and summer of 1957, the author collected in 151 stations which covered 19 of the 21 counties of New Jersey. More Stations were established in counties in which crayfish were scarce than in those where crayfish were found to be abundant. Fifty-one of the 150 locations yielded at least one specimen.

Collection data from the American Museum of Natural History, the Academy of Natural Sciences of Philadelphia, the United States National Museum, the Museum of Comparative Zoology, and Mr. Roland Smith, Principal Fisheries Biologist of New Jersey were examined by the author. Collection data and two live *Cambarus diogenes* were received from Mr. J. Albert Starkey of Vineland, New Jersey. The collections of the Academy of Natural Sciences of Philadelphia and the American Museum of Natural History were examined and a specimen of *Cambarus diogenes* was obtained on loan from the United States National Museum. Together with published records of New Jersey crayfishes, the data herein contained represent records from 138 stations (some of which are duplicates) in every county of the state except Hudson.

Collecting was done by the author with common seine, dip net, and by hand. All specimens were preserved in 80 percent ethyl alcohol. Hydrogen-ion concentration of all waters was determined with Lamott colormetric pH indicators.

The drawings (fig. 1, 3, 5, and 7) of the chelae and carapaces are based on actual measurements of the crayfish made with dividers and transferred to the paper. Those of the seminal receptacles and gonopods are camera lucida drawings. Obvious pubescence has been indicated, but no indication of this on the drawing does not necessarily indicate a lack of pubescence on the specimen. The curvature of the various parts has been indicated by stippling. A solid line indicates an actual structure on the animal.

The following abbreviations will be used where applicable throughout this paper:

AMNH—American Museum of Natural History
ANSP —Academy of Natural Sciences of Philadelphia
MCZ —Museum of Comparative Zoology
NYSM —New York State Museum
USNM —United States National Museum
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Systematic List of New Jersey Crayfishes

Procambarus Ortmann, (1905b: 437).
Blandingi Section (Ortmann, 1905a: 98).
Blandingi Group (Ortmann, 1905a: 102).
Blandingi Subgroup (Hobbs, 1942b: 93).
Procambarus blandingi blandingi (Harlan), 1830.
Orconectes Cope, (1872: 419).
Limosus Section (Ortmann, 1905a: 108).
Orconectes limosus (Rafinesque), 1817.
Cambarus Erichson, (1846: 88).
Bartoni Section (Ortmann, 1905a: 119).
Cambarus bartoni bartoni (Fabricius), 1798.
Diogenes Section (Ortmann, 1905a: 119).
Cambarus diogenes Girard, 1852.

Key to the Known Crayfishes of New Jersey

A. Rostrum without lateral spines; margins subparallel, forming rounded shoulders as they converge into a terminal blunt spine.
B. Areolae narrowly linear or obliterated. . . . *Cambarus diogenes* (fig. 7).
BB. Areolae broad and short. . . . . *Cambarus bartoni bartoni* (fig. 5).
AA. Rostrum with lateral spines and without rounded shoulders.
B. Rostrum large with broad base, margins uniformly converging to an acute tip; small lateral spines located very close to tip. . . . . *Procambarus blandingi blandingi* (fig. 1).
BB. Rostrum deeply concave with margins nearly parallel; lateral spines large and conspicuous. . . . . *Orconectes limosus* (fig. 3).

Hydrogen-Ion Concentration

An ecological factor which varies considerably in the open water of the State of New Jersey is the hydrogen-ion concentration or pH. This ranges from a pH of 3.8 in some of the "cedar waters" of the Atlantic coastal plain in the southeast to 9.5 in the glaciated piedmont plateau of northern New Jersey. In the collections made by the author the following ranges of pH were observed for the crayfishes found in the state:

Procambarus blandingi blandingi	3.8 to 8.5
Orconectes limosus	6.4 to 9.4
Cambarus bartoni bartoni	7.6 to 8.5
Cambarus diogenes	no data

The significance of low or high pH upon crayfish is difficult to determine, but certain observations have been made. In the acid waters of the state the most striking and frustrating feature is the scarcity of crayfish. The author has collected extensively in acid waters were reliable zoologists had reported crayfish, but failed to take one. Crayfish of the acid waters have much thinner exoskeletons than do individuals of the same species from more alkaline waters. This was observed even in some large form I males. This may be due to the low calcium content of the water.

Mr. Roland Smith, Principal Fisheries Biologist of New Jersey, reports (personal communication) that crayfish in the acid waters of the state are a preferred food of the Eastern Chain Pickerel. This is not clearly understood, but perhaps it is associated with the fact that the crayfish of these waters have very thin shells.

Whether pH is a limiting factor in the distribution of crayfish is uncertain. The lack of typical *Cambarus bartoni bartoni* habitat in the Atlantic coastal plain

undoubtedly has restricted this species to northern New Jersey. The normal habitat of *Orconectes limosus*, however, differs from that of the Atlantic coastal plain only in pH. Hence the acidity of the water probably has played a major role in keeping *O. limosus* out of the Atlantic coastal plain.

Procambarus blandingi blandingi (Harlan)

Figures 1 and 2

Astacus blandingi Harlan, 1830: 464–465.
Astacus (Cambarus) blandingi Erickson, 1846: 98–99.
Cambarus blandingi Hagen, 1870: 43–45.
Cambarus acutus Abbott, 1873: 80–84.
Cambarus (Cambarus) blandingi Ortmann, 1905a: 96–97.
Cambarus (Ortmannicus) blandingi Fowler, 1912: 340–341.
Cambarus blandingi acutus Faxon, 1914: 367.
Procambarus blandingi blandingi Hobbs, 1942a: 341–342.

Type locality.—"Marshes and rivulets, Southern United States [Camden, Kershaw Co., S. C.?]" Faxon (1914: 413).

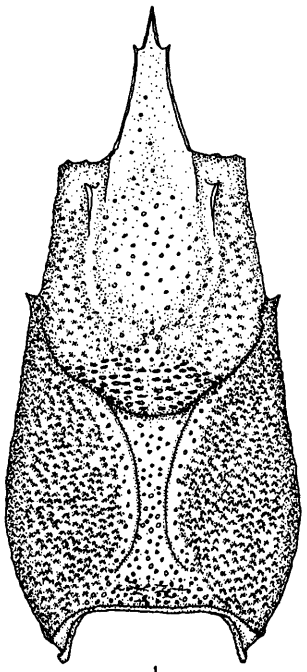
Taxonomic remarks.—Crocker (1957: 30) gives a complete description of a form I male and a female from the Bronx River in Westchester County, New York. The *P. b. blandingi* examined from New Jersey agree with Crocker's description in most respects. There are, however, certain differences which were observed in the New Jersey specimens. Crocker describes the carapace as covered with tubercules and granular to the touch. In the New Jersey specimens these tubercules are often so reduced that the carapace feels smooth. The areolae of all New Jersey specimens examined have at least two and often three rows of punctations at the narrowest point (fig. 1.1) in contrast to the one row of punctations at the narrowest point described by Crocker.

The chelae of the New Jersey *P. b. blandingi* (fig. 1.2) show great variation. They are generally small and weakly developed and in some of the smaller specimens but slightly larger than the second pair of walking legs. In the larger and presumably older specimens the chelae are longer, stouter, and generally better developed. The number of tubercules and their arrangement on the inner edges of the fingers of the New Jersey specimens vary with no apparent trend in their frequency or location. In older specimens it is possible to separate the sexes by the size and shape of the chelae alone. The females have shorter, stouter chelae while the males have chelae that are longer and narrower. The notch at the base of the movable fingers of females and the bladelike setae on the inner surface of the fingers of males described by Crocker is evident only in some New Jersey specimens. This appears to be associated with aging, but not enough material is available to diagnose these variable characters accurately. The seminal receptacles (fig. 1.4) of the females examined exhibited a variety of shapes and seem to be of little taxonomic value.

Habits.—*Procambarus blandingi blandingi* usually are found associated with aquatic vegetation. They are found, however, in bodies of water that have very little vegetation as Stephens Creek at Estellville in Atlantic County. In this creek a form I male was collected from under a log on a gravel bottom. In Maryland this species is reported to make burrows and inhabit the salt marshes which are covered twice daily by the tides (Faxon, 1885b: 23). No crayfish were found inhabiting the salt marshes of New Jersey. This species also is reported to occur in polluted water in association with decaying vegetation and deep muck (Crocker, 1957: 69).

EXPLANATION OF FIGURES

FIGURE 1. *Procambarus blandingi blandingi.* **1.** Carapace. Male, carapace length 40 mm. Stephens Creek at Route 50, Estellville, Atlantic County, September 24, 1957. DDF 63. **2.** Right chela. Same specimen as number 1. **3.** Lateral aspect of right form I gonopod. Same specimen as number 1. **4.** Seminal receptacle. Female, carapace length 37 mm. Greenwood Lake, Hewett, Passaic County, March 15, 1957. DDF 9. **5.** Lateral aspect of right form II gonopod. Male, carapace length 30 mm. Oyster Creek at Route 9, Waretown, Ocean County, June 21, 1957. DDF 44.



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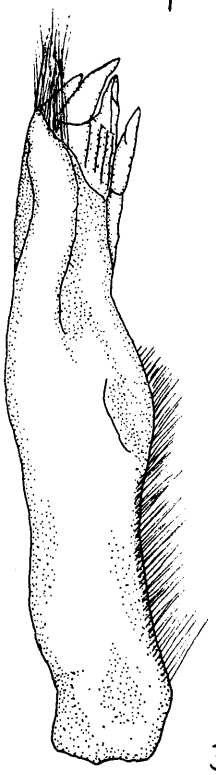

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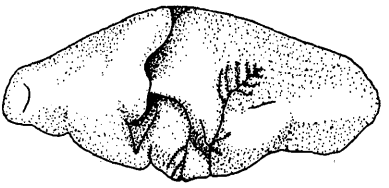

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In New Jersey this species is found in small creeks, large sluggish rivers, and lakes. These bodies of water exhibit a great diversity of ecological conditions. Some of the streams in which *P. b. blandingi* are found are crystal clear, cold, and have a high hydrogen-ion concentration (pH 3.8) while others are muddy, warm, and alkaline (pH 8.5). The lakes in which they are found also vary in nature. This species has a great range of tolerence of such variable factors as pH, pollution, temperature, vegetation, turbidity, and bottom composition.

Life history.—Little information is available. There are no records of females with eggs or young and no observations of copulation. Crocker (1957: 68) reports a female with a sperm plug collected in August. The author has collected females in March with sperm plugs. Form I males have been collected in June, July, August, and September. On the basis of this fragmentary evidence, mating probably occurs in the late summer and fall and spawning in the spring.

Distribution.—This species inhabits most or all of the Atlantic coastal plain and has been collected as far north as Greenwood Lake in New York State (fig. 2). Greenwood Lake lies half in New York and half in New Jersey in mountainous country deep in the glaciated area. Crocker (1957: 71) states, "*P. b. blandingi* . . . has not left its lowland habitat." This is in error, but to what extent it has invaded the glaciated area is uncertain. This species possibly extends much farther into New York State than we are aware. *Procambarus blandingi blandingi* is able to exist in small, inconspicuous populations that easily escape detection. In some lakes extensive collecting yielded no crayfish yet a pickerel from the same water contained a specimen of this species.

Ortmann (1905a: 103–106) places the origin of the genus *Procambarus* in Mexico and the center of the Blandingi Section in Alabama and Georgia. He postulates that it entered Florida and spread northeastward along the Atlantic coastal plain. All available evidence supports this theory.

New Jersey Records of Procambarus blandingi blandingi

Atlantic County

Nacote Lake (from stomach of pickerel), Port Republic, Aug. 29, 1957. DDF 58.
Stephens Creek at Route 50, Estellville, Sept. 24, 1957. DDF 63.
Batso Pond (Batso River), Batso. J. A. Starkey. Personal communication.
Branch of Little Egg Harbor River, Folsom. J. A. Starkey. Personal communication.

Burlington County

Medford Lakes, June 5, 1903. S. N. Rhoads. ANSP 1570.
Chatsworth Lake, Chatsworth, Sept. 15, 1957. DDF 59.

Cumberland County

Vineland, 1950. J. A. Starkey. USNM 91425.
Little Robin Branch of Maurice River, Vineland. J. A. Starkey. Personal communication.
Maurice River at Almond Road Bridge. J. A. Starkey. Personal communication.

Essex County

Essex County. Faxon (1885b: 19).

Gloucester County

Repauto Creek, Repauto, April 19, 1908. B. N. Griffiths and H. W. Fowler. ANSP 4828.
Mantua Creek, Mantua, April 8, 1906. H. W. Fowler and S. H. Hamilton. ANSP 5647 and 4826.
Racoon Creek at Route 45, Mullica Hill, Sept. 15, 1957. DDF 60.
Branch of Upper Egg Harbor River, Downstown. J. A. Starkey. Personal communication.

Mercer County

Tributary of Crosswicks Creek, Trenton, July 13, 1901. H. W. Fowler, T. D. Keim, and C. B. Abbott. ANSP 4827.

Millpond at Grover's Mills, Princeton Junction. Ortmann (1905a: 131).
Delaware-Raritan Canal, aqueduct near Princeton. Ortmann (1905a: 131).
Trenton. Abbott (1873: 80).
Delaware River and tributaries, Trenton. Faxon (1885b: 19).

Middlesex County

Farrington Lake at Route 130, South Brunswick, March 18, 1957. DDF 17.
Millpond, Plainsboro. Ortmann (1905a: 131).

Ocean County

Mill Creek at Route 9, Manahawken, June 21, 1957. DDF 43.
Oyster Creek at Route 9, Waretown, June 21, 1957. DDF 44.
Oyster Creek, 1953. R. Smith. Personal communication.

Passaic County

Greenwood Lake, Hewett, March 15, 1957. DDF 9.

FIGURE 2. Stream map of New Jersey showing locations of collections of *Procambarus blandingi blandingi*.

Salem County

Allowaystown, Sept. 7, 1901. H. W. Fowler, and S. N. Rhoads. ANSP 5296.
Branch of Muddy Brook near Palatine Lake, 1949. J. A. Starkey. USNM 92917.
Muddy Run Brook at Jesse's Bridge, Norma. J. A. Starkey. Personal communication.
Muddy Run Brook, Elmer. J. A. Starkey. Personal communication.

Localities from which crayfish, which are presumed to be *Procambarus blandingi blandingi*, have been taken:
Hammonton Lake, Hammonton, Atlantic County. R. Smith. Personal communication.

Absegami Lake, Bass River State Forest. Burlington County. R. Smith. Personal communication.
Manasquam River, Monmouth County. R. Smith. Personal communication.
Deer Head Lake, Toms River, Ocean County. R. Smith. Personal communication.
Upper Takanassee Lake, Ocean County. R. Smith. Personal communication.
Upper section of Maurice River, Salem County. R. Smith. Personal communication.

Orconectes limosus (Rafinesque)

Figures 3 and 4

Astacus limosus Rafinesque, November 1817: 42.
Astacus affinis Say, December 1817: 168.
Astacus bartoni Milne-Edwards, 1837: 331.
Astacus (Cambarus) affinis Erichson, 1846: 96.
Cambarus affinis Girard, 1852: 87.
Cambarus pealei Girard, 1852: 87.
Cambarus (Faxonius) limosus Ortmann, 1905a: 107.
Orconectes limosus Hobbs, 1942a: 352.

Type locality.—". . . muddy banks of the Delaware, near Philadelphia." Rafinesque, 1817: 42.

Taxonomic remarks.—*Orconectes limosus* examined from New Jersey agree with the excellent diagnoses of Ortmann (1906: 352–356) and Fowler (1912: 354–356). The specimens of *O. limosus* examined by Ortmann included 54 from New Jersey.

Habits.—Fowler (1912: 357) characterizes *O. limosus*: "The river crayfish does not make much, if any, of a burrow, but usually hides under stones or in aquatic vegetation. It also does not live in rough rocky streams, but inhabits quiet or tidal fresh waters. . . ." With a few exceptions, this description is acceptable. The author has often taken *O. limosus* in quite swift water and from a rocky bottom. In primrose Brook, a tiny stream near Morristown, this species was collected along with *Cambarus bartoni bartoni* from beneath the rocks of a small rock dam. If there are rocks or rubble present in a stream, this probably is the best place in which to look for *O. limosus*, but stands of aquatic vegetation also should be examined.

Most authorities agree that *O. limosus* is not a burrowing crayfish. In Van Saun Brook, Riveredge, the author has observed and collected it in burrows. The burrows were made in a clay bank under water. They were 9 to 16 in. deep with very few branches or side tunnels. The observations and collection were made in March and include one copulating pair. This pair will be discussed in more detail under the life history of this species.

Life history.—Ortmann (1906: 478) summarizes the life history of *O. limosus* by noting, "The mating season in the fall, the spawning season in spring, and the absence of males of the first form in early summer (June and part of July). . . ." Ortmann takes exception the work of Andrews (1904: 166) who states that the normal mating season is in the months of February, March, and early April. Andrews also is of the opinion that there is an autumnal pairing in October or November ". . . in place of or in addition to the spring pairing." Ortmann feels that Andrews' observations, which were made in the laboratory, lead to an error, the warm water in the laboratory in March causing the crayfish to copulate unseasonally.

The author's observations of *O. limosus* copulating in March tend to endorse Andrews' work. The copulating pair was captured by reaching into a burrow and grasping the two crayfish. When withdrawn from the burrow, the crayfish were in a copulating position; however,

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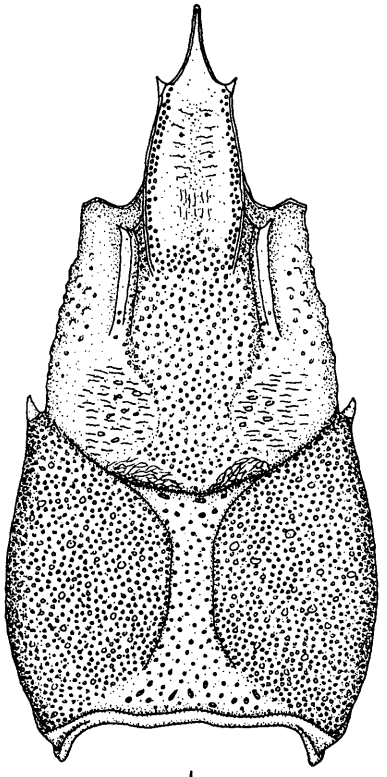
EXPLANATION OF FIGURES

FIGURE 3. *Orconectes limosus*. **1.** Carapace. Male, carapace length 36 mm. Van Saun Brook, Riveredge, Bergen County, August 21, 1957. DDF 45. **2.** Right chela. Same specimen as number 2. **3.** Lateral aspect of right form I gonopod. Same specimen as number 1. **4.** Seminal receptacle. Female, carapace length 37 mm. Van Saun Brook, Riveredge, Bergen County, August 21, 1957. DDF 45. **5.** Lateral aspect of right form II gonopod. Male, carapace length 33 mm. Greenwood Lake, Hewett, Passaic County, June 8, 1957. DDF 33.



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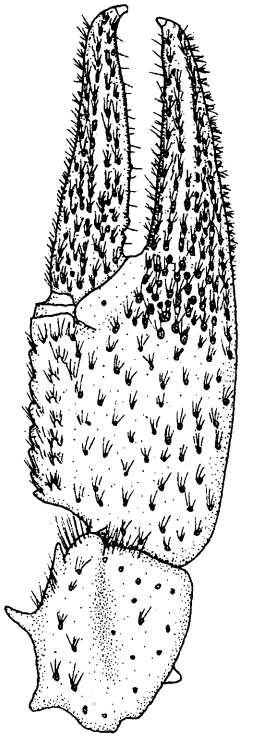

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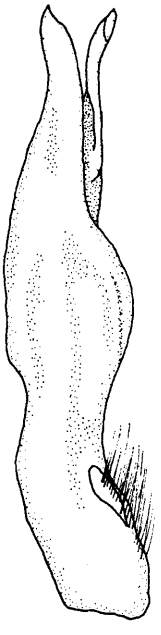

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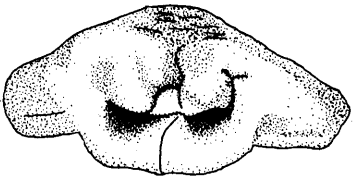

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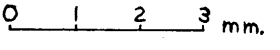

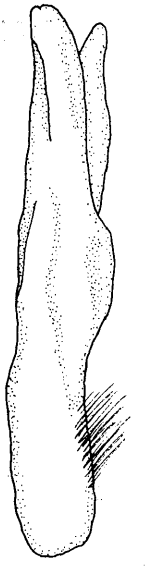

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they separated before they could be examined closely. This female was the only one in this collection. The other eight crayfish taken were first form males. Some of the males were collected in burrows and others in depressions in the stream bed where they were seen easily and caught.

This same stream was revisited on August 21, 1957, and a large number of copulating *O. limosus* was found. They were not easily disturbed and could be handled and taken out of the water without separating. The position and maneuvers of the males in copulation and approach to copulation were identical with Andrews' observations.

The author is of the opinion that mating of *O. limosus* usually occurs in the late summer and fall. Perhaps there is a supplemental spring mating season or perhaps they may copulate irregularly through the winter. The bulk of evidence available, however, indicates a fall mating season. More information is needed before the significance of this March copulation record is fully understood.

The smallest form I male *O. limosus* (ANSP 5320) examined had a carapace 19 mm long and was collected by E. S. and W. L. Mattern from Schwartzwood Lake outlet on October 21, 1917. A female of this species (NYSM 7000) with a carapace 22.5 mm long and with a sperm plug was collected by D. W. Crocker (1957: 56). These are the smallest sexually mature *O. limosus* recorded.

Ortmann (1906: 479) found a female with eggs on May 9 and a female with young on May 30. The author collected a female with young from Greenwood Lake on June 8.

Ortmann (1906: 479) observed copulation of this species in January and again on November 4 in the laboratory, but only on September 4 and 10 in the field. The author has observed copulation of this species on March 14 and August 21.

Distribution.—Undisputed records of *O. limosus* are from the states of Pennsylvania, Virginia, District of Columbia, Maryland, New Jersey and New York (Crocker, 1957: 78). In New Jersey this species is found in the Delaware River drainage, extending into the Atlantic coastal plain and in glaciated northern New Jersey (fig. 4). The one exception to this is Faxon's (1885b: 86) record for Red Bank, presumably from the Navesink River. The headwaters of the Navesink and the headwaters of a branch of the Raritan River are only a few miles apart in the lowlands north of Freehold. They no doubt have been connected at one time and the southern migration of *O. limosus* effected by this connection.

The crayfishes with the closest affinities to *O. limosus* are found in the Mississippi drainage in Kentucky, Missouri, and Indiana. The origin of the Limosus Section of *Orconectes* is in the central part of the Mississippi drainage. The present morphological and geographical isolation of *O. limosus* indicates the antiquity of the Limosus Section (Ortmann, 1906: 428–432). Ortmann further states, "*Cambarus limosus* is a Tertiary type and it reached its present area coming from the west and by way of the north, being driven south along the Atlantic Coastal Plain by the advancing ice of the Glacial Period." When Ortmann wrote this he was not aware of the present range of *O. limosus* into New York state or even that it positively existed north of New Jersey. With the knowledge of the distribution of this species in New York now available (Crocker, 1957), there is little doubt that it reached its present distribution by the route outlined by Ortmann.

New Jersey Records of Orconectes limosus

Bergen County

Van Saun Brook, Riveredge, March 14, 1957. DDF 3.
Saddle River at Route 4, Ridgewood, March 15, 1957. DDF 4.
Ramapo River at Glen Gray Bridge, Oakland, March 15, 1957. DDF 7.
Van Saun Brook, Riveredge, August 21, 1957. DDF 45.

Burlington County

Medford Mills, June 5, 1903. S. N. Rhoads. ANSP 5611.
North Creek, Burlington, May 29, 1910. H. W. Fowler and T. D. Keim. ANSP 5083.
Delaware River, Bordentown, August 29, 1909. C. C. Abbott, T. D. Keim, and H. W. Fowler. ANSP 5084.

Florence Creek, Florence, May 15, 1910. H. W. Fowler. ANSP 5171.
Below Burlington, June 17, 1910. H. W. Fowler. ANSP 5170.
Blacks Creek at Route 206, Bordentown, August 23, 1957. DDF 56.
North Branch of Rancocas Creek at Route 206, Mount Holly, August 23, 1957. DDF 57.
Burlington Islands. Fowler (1912: 357).
Burlington. Faxon (1885b: 86).
Burlington Islands, April 16, 1884. C. C. Abbott. MCZ 3688.

Camden County

Coopers Creek, Camden, Oct. 29, 1916. J. Aebley. ANSP 5610.
Camden, E. Dittenbaugh. ANSP 409.
Delaware River, North Cramer Hill, Sept. 1904. Ortmann (1905a: 131).
Delaware River, Camden. Ortmann (1906: 357).

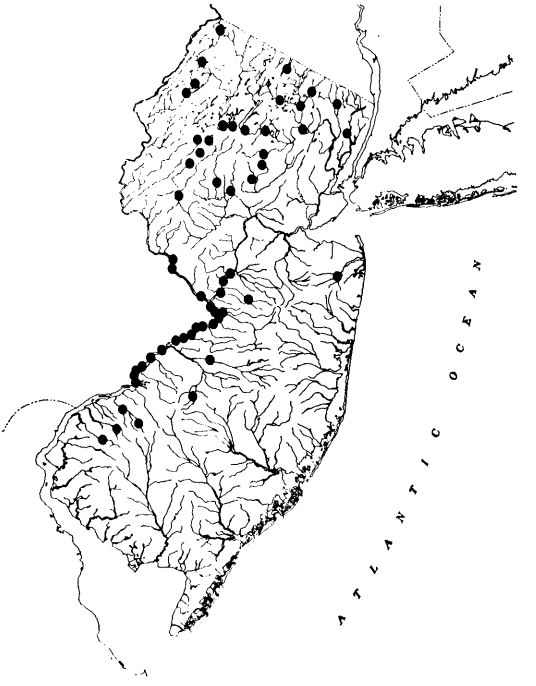


FIGURE 4. Stream map of New Jersey showing locations of collections of *Orconectes limosus*.

Gloucester County

Alycon Dam, Pitman, Oct. 1, 1909. H. W. Fowler and H. L. Mather. ANSP 5173.
Mantua Creek, Mantua, April 8, 1906. H. W. Fowler and S. H. Hamilton. ANSP 1667.
Racoon Creek at Route 45, Mullica Hill, Sept. 15, 1957. DDF 61.
Oldmans Creek at Route 45, Harrisonville, Sept. 15, 1957. DDF 62.

Hunterdon County

Alexsocken Creek above Lambertsville, July 27, 1914. H. W. Fowler and H. H. Burton. ANSP 5313.
Lamington River at County Road 523, Lamington, Aug. 22, 1957. DDF 52.
Branch of South Branch of Raritan River at Route 22, Clinton, Aug. 22, 1957. DDF 53.

Mercer County

Crosswicks Creek, Trenton, May 21, 1905. H. W. Fowler. ANSP 5090.
Delaware River, Duck Island, Aug. 20, 1909. H. W. Fowler, C. C. Abbott, and T. D. Keim. ANSP 5018.
Assunpink Creek at Route 130, Windsor, March 18, 1957. DDF 18.
Baker Basin Creek, Lawrence, Aug. 23, 1957. DDF 55.
Stony Brook, Princeton, Sept. and May 30, 1898. Ortmann (1905a: 131).
Delaware-Raritan Canal at aqueduct, Princeton, Jan. 1899. Ortmann (1905a: 131).
Trenton. Abbott (1873: 80).
Trenton. Faxon (1885b: 86).
Assumgerich (?) Creek, July 24, 1884. MCZ 12640.

Monmouth County

Red Bank. Faxon (1885b: 86).

Morris County

Hurd Cove, Lake Hopatcong, Sept. 25, 1916. R. H. Abbott and H. W. Fowler. ANSP 5174.
Rockaway River, Denville, March 16, 1957. DDF 10.
South Branch Raritan River at Route 46, Budd Lake, March 16, 1957. DDF 11.
Musconetcong River at Route 46, Hackettstown, March 16, 1957. DDF 12.
Branch of Rockaway River from Lake Hopatcong at Route 15, Jefferson Twsp., March 16, 1957. DDF 16.
Dover, July 1884. C. C. Abbott. MCZ 3753.
Whippany River at Route 202, Morristown, August 22, 1957. DDF 47.
Primrose Brook at Route 202, Jockey Hollow, Morristown, Aug. 22, 1957. DDF 48.
Schooley's Mountain. Faxon (1885b: 86).
Schooley's Mountain. A. Mayor. MCZ 3452.

Passaic County

Greenwood Lake, Hewett, March 15, 1957. DDF 8.
Pequanock River at Dam on Route 23, West Milford, June 9, 1957. DDF 35.
Signac Brook at Route 46, Signac, Aug. 22, 1957. DDF 46.
Pompton Lake, July 20, 1936. J. A. Chuver (?). MCZ 9566.

Sussex County

Schwartzwood Lake, Oct. 5, 1895. S. N. Rhoads. ANSP 5612.
Schwartzwood Lake Outlet, Oct. 21, 1917. E. S. and M. L. Mattern. ANSP 5320.
Saw Mill Lake, Stokes State Forest, June 9, 1957. DDF 39.
Culvers Lake at Route 206, Branchville, June 9, 1957. DDF 41.

Sommerset County

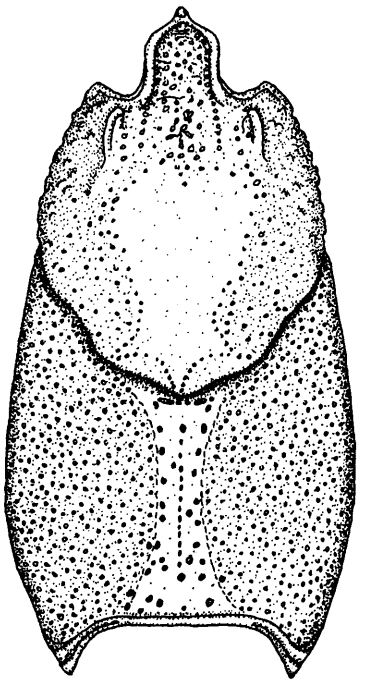
Passaic River at Route 202, Bernardsville, Aug. 22, 1957. DDF 50.
North Branch Raritan River at Route 202, Far Hills, Aug. 22, 1957. DDF 51.

Warren County

Musconetcong River, Port Clinton, Aug. 8, 1916. H. W. Fowler and W. L. Mattern. ANSP 5305.

EXPLANATION OF FIGURES

FIGURE 5. *Cambarus bartoni bartoni*. **1.** Carapace. Male, carapace length 30 mm. Delaware Creek one-half mile from Delaware River, Delaware, Warren County, March 16, 1957. DDF 15. **2.** Right chela. Same specimen as number 1. **3.** Lateral aspect of right form I gonopod. Same specimen as number 1. **4.** Seminal receptacle. Female, carapace length 28 mm. Musconetcong River, Hackettstown, Morris County, March 16, 1957. DDF 13. **5.** Lateral aspect of right form II gonopod. Male, carapace length 26 mm. Little Flat Brook, Hainsville, Sussex County, June 9, 1957. DDF 40.



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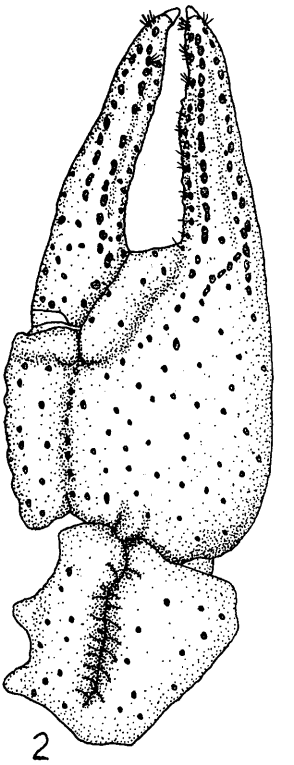

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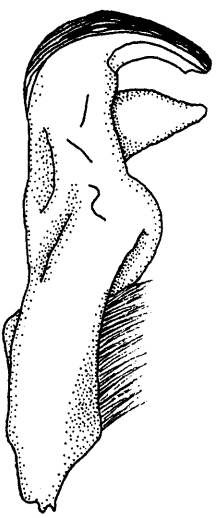

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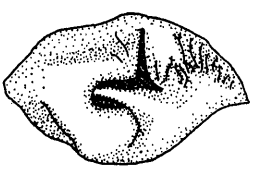

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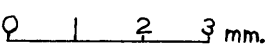

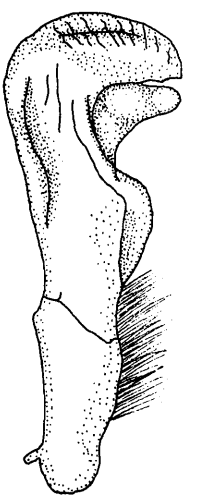

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New Jersey localities not known

Hamilton, Mexico (?) County, June 1, 1884. W. Faxon. MCZ 3687.
Delaware River, Newbold Island, Aug. 13, 1908. H. W. Fowler and T. D. Keim. ANSP 5089.
Tienehill Hill west of Dundee Bridge, May 4, 1901. E. Smith. AMNH 4042 and 4040.
Mt. Abry. Hagen (1870: 60).
Fornton, Nov. 26, 1872. C. C. Abbott. MCZ 3538.

Delaware River localities on Pennsylvania side

Philadelphia County

Holmsburg, July 4, 1898. H. W. Fowler. ANSP 1355.
Holmsburg, July 4, 1899. H. W. Fowler. ANSP 1453.
Holmsburg, Sept. 1904. Ortmann (1905a: 131).
Torresdale Fish Hatchery, Oct. 26, 1911. H. W. Fowler and J. R. Berkhouse. ANSP 5166.
Near Philadelphia. Rafinesque (1817: 42).
Torresdale Fish Hatchery, Sept. 1904. Ortmann (1905a: 131).

Bucks County

Below Bristol, May 12, 1908. H. W. Fowler and T. D. Keim. ANSP 5300.
New Hope, Sept. 1904. Ortmann (1905a: 131).
Penns Manor. Ortmann (1906: 356).
Bristol. Faxon (1885b: 87).

Cambarus bartoni bartoni (Fabricius)

Figures 5 and 6

Astacus bartoni Fabricius, 1798: 407.
Astacus ciliaris Rafinesque, 1817: 42.
Astacus pusillus Rafinesque, 1817: 42.
Astacus affinis Milne-Edwards, 1837: 332.
Cambarus bartoni Girard, 1852: 88.
Cambarus montanus Girard, 1852: 88.
Cambarus pusillus Girard, 1852: 88.
Cambarus (*Bartonius*) *bartoni* Ortmann, 1905a: 117.
Cambarus (*Ortmannicus*) *bartoni* Fowler, 1912: 340–341.

Type locality.—"Habitat in America Boreali." Fabricius (1798: 407).

Taxonomic remarks.—New Jersey specimens of *C. b. bartoni* agree with the excellent descriptions given by Ortmann (1906: 377–380) and Fowler (1912: 344–347). There are many subspecies of *C. bartoni* and much intergradation and regional variation exist. Since the type specimen of this species probably was collected near Philadelphia the New Jersey, *C. b. bartoni* may be taxonomically closer to this than specimens from any other part of the country. Mr. Rendell Rhoades (personal communication) has commented that the *C. b. bartoni* from the midwest are as different from the typical eastern form as many described subspecies. The *bartoni* complex is indeed complicated and much more work is needed before it is completely understood.

Habits.—*Cambarus bartoni bartoni* is almost invariably found in small streams having cold, well oxygenated water, and on a bottom of stones, sand and gravel, or rubble. The author has not taken this species from a lake, but has examined a form I male from Schwartzwood Lake collected by S. N. Rhoads (ANSP 1308). *Cambarus bartoni bartoni* was collected from the Musconetcong River at Hackettstown along with *Orconectes* limosus. The Musconetcong is about 80 ft wide at this point. The specimen was collected near the bank in two ft of water. While the Musconetcong is a clean, well oxygenated river, it is large and does warm up considerably in the summer. This species may be considered, however, as a crayfish of the small, cold mountain streams. *Cambarus bartoni bartoni* also is found at considerable elevations as Lake Marcia near High Point.

The burrows of this species are made in the bank or in the stream bed under stones or rubble, where they may be quite elaborate. The burrows in the stream bed are detected easily in the

warmer months, when the crayfish are more active, by the fresh sand deposited at the entrance. Several times the author has removed one stone after another from the labyrinth of the burrow only to discover that the crayfish had left by another tunnel and was a few feet up stream.

Life history.—Seasonal data of the New Jersey *C. b. bartoni* agree with the life history information for this species given by Ortmann (1906: 487) and Crocker (1957: 65–68). Ortmann states, ". . . very likely *C. bartoni* has no defined spawning-season, but may spawn at any time of the year and that accordingly the mating-season is also not restricted to a particular time of the year." Ortmann further postulates that the uniform temperature of the streams where this species is found is responsible for the year around spawning season. Form I males have been found in every month of the year except January and February. This is undoubtedly due to the fact that very little collecting is done in January and February.

Distribution.—Cambarus bartoni bartoni is widely distributed from Tennessee to Maine and New Brunswick and westward to Indiana (Ortmann, 1905a: 122). Ortmann further states, "Eastward, it hardly descends to the Atlantic Plain, at any rate it does not spread over it. . . ." In New Jersey the species descends to the edge of the Atlantic coastal plain and inhabits the glaciated piedmont plateau area north of Trenton (fig. 6). This species had its origin in the Southern Appalachian system and migrated north along the mountains (Ortmann, 1906: 447).

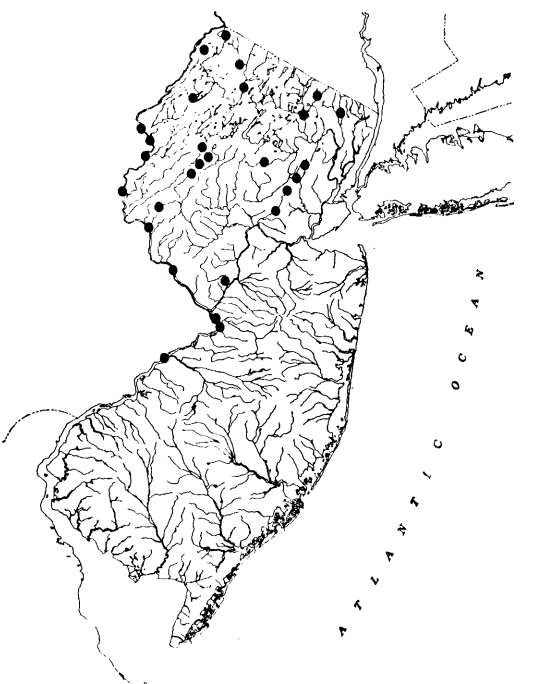


FIGURE 6. Stream map of New Jersey showing locations of collections of *Cambarus bartoni bartoni*.

New Jersey Records of Cambarus bartoni bartoni

Bergen County

Saddle River at Route 4, Ridgewood, March 15, 1957. DDF 5.
Bear Swamp Brook, Darlington, March 15, 1957. DDF 6.

Essex County

Maplewood, July 1892. E. W. Smith. AMNH 252.
Orange. Faxon (1885b: 60).

Hunterdon County

Mulhocaway Creek at Route 22, Pattenburg, Aug. 22, 1957. DDF 54.
Stream flowing into Delaware River, Milford, May 29, 1935. H. Darby. USNM 74672.

Mercer County

Small streams near Princeton. Ortmann (1905a: 34).
Delaware River, Trenton. Abbott (1873: 80).
Trenton. Faxon (1885b: 60).

Morris County

Schooley's Mountain. Faxon (1885b: 60).
Schooley's Mountain, May 21, 1910. F. E. Lutz. AMNH 3988.
Musconetcong River at Route 46, Hackettstown, March 15, 1957. DDF 13.
Primrose Brook at Route 22, Jockey Hollow, Morristown, Aug. 22, 1957. DDF 49.
Schooley's Mountain. Hagen (1870: 75).

Passaic County

Pompton, May 1, 1910. F. W. Lutz. AMNH 4004.

Sussex County

Schwartzwood Lake, Oct. 5, 1895. S. N. Rhoads. ANSP 1308.
Branch of Franklin Lake at Route 23, Franklin, June 9, 1957. DDF 36.
Clove Brook at Route 23, Sussex, June 9, 1957. DDF 37.
Lake Marcia at High Point, Stokes State Forest, June 9, 1957. DDF 38.
Little Flat Brook at Route 206, Hainsville, June 9, 1957. DDF 40.

Union County

Plainfield, April 9, 1922. B. J. B. Hyde. AMNH 4025.
Green Brook, Scotch Plains, June 9, 1957. J. Krivacs and G. Bachofen. DDF 42.

Warren County

Beaver Brook at Pequest River, Belvidere Junction, March 16, 1957. DDF 14.
Delaware Creek, one half mile from Delaware River, Delaware, March 16, 1957. DDF 15.

Delaware River localities on Pennsylvania side

Bucks County

New Hope. Ortmann (1905a: 135).

Northhampton County

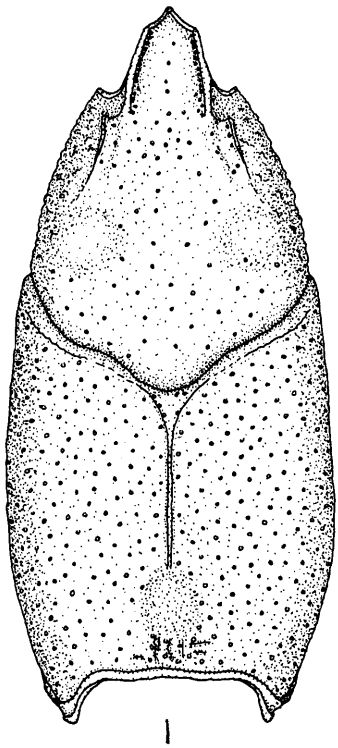
Easton. Ortmann (1906: 381).
Portland. Ortmann (1906: 385).

Philadelphia County

Holmsburg. Ortmann (1906: 384).

EXPLANATION OF FIGURES

FIGURE 7. *Cambarus diogenes*. **1.** Carapace. Male, carapace length 45 mm. Cohansey Creek, Bridgeton, Cumberland County, summer 1951. J. A. Starkey. USNM 92916. **2.** Right chela. Same specimen as number 1. **3.** Lateral aspect of right form I gonopod. Same specimen as number 1. **4.** Seminal receptacle. Female, carapace length 35 mm. Near Davis' Mill, seven miles west of Bridgeton, Cumberland County, May 25, 1958. J. A. Starkey. DDF 78. **5.** Lateral aspect of right form II gonopod. Male, carapace length 30 mm. Near Davis' Mill, seven miles west of Bridgeton, Cumberland County, May 25, 1958. J. A. Starkey. DDF 78.



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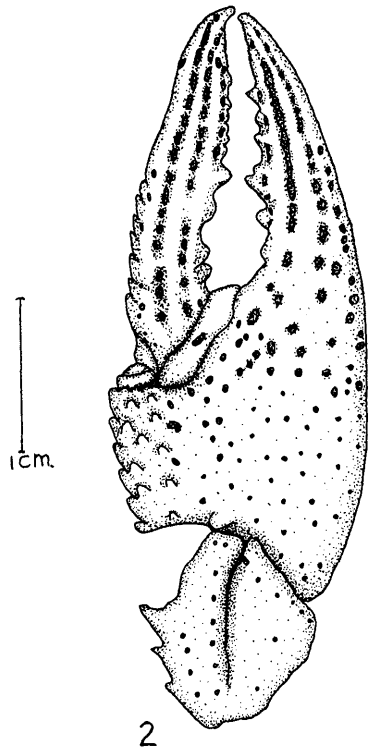

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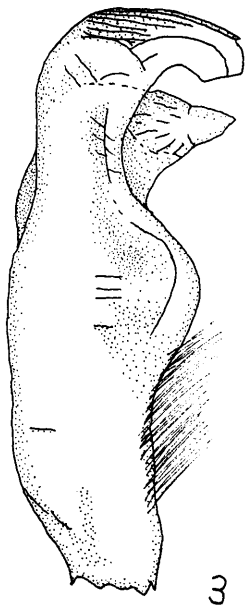

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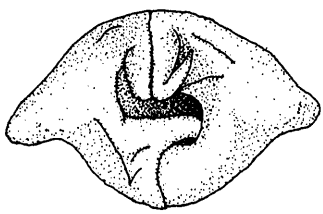

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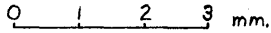

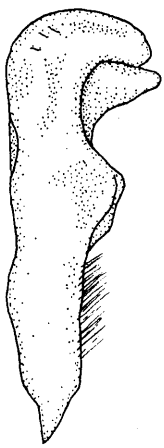

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Cambarus diogenes Girard

Figures 7 and 8

Cambarus diogenes Girard, 1852: 88.
Cambarus obesus Hagen, 1870: 81.
Cambarus diogenenes Abbott, 1873: 83.
Cambarus diogenes ludovicianus Faxon, 1884: 144.
Cambarus dubius Osborn and Williamson, 1898: 144.
Cambarus (Bartonius) diogenes Ortmann, 1905a: 120.
Cambarus (Ortmannicus) diogenes Fowler, 1912: 340.

Type locality.—Washington, D. C. Girard (1852: 88).

Taxonomic remarks.—Ortmann (1906: 407–409) recognized eastern and western forms of *C. diogenes*. Those found in New Jersey are of the eastern form. Only three New Jersey specimens of this species were examined by the author, a form I male (USNM 92916) collected by Mr. J. Albert Starkey at Bridgeton (fig. 7) and a form II male and a female with young (DDF 78) collected by Mr. J. Albert Starkey near Davis' Mill, seven miles west of Bridgeton. These specimens follow very closely the description of the eastern form of *C. diogenes* given by Ortmann.

The following differences were noted between these specimens and the typical western form. The areola is not completely obliterated as in the western form and the fingers of the chelae are considerably longer than the palm as contrasted to fingers approximately the same length as the palm in western specimens. There is a distinct notch at the base of the fingers in the eastern form caused by the arrangement of the tubercules on the movable finger. This notch is not apparent in the western form of this species. There is a lack of tuberculation on the dorsal surface of the palm in the New Jersey specimens, the tubercules being restricted to two rows on the inner edge. In the western form the tuberculation often extends half way across the dorsal surface of the palm. The most striking difference between the eastern and western forms is in the structure of the rostrum. Ortmann notes a tendency toward an acumen in the eastern form, but was not aware of its exact physical structure. Close examination of the New Jersey specimens shows that the swollen lateral margins of the rostrum terminate about four-fifths of the way along the rostrum while the supra-orbital ridges continue to the tip forming the acumen. In contrast, the western form has the lateral swollen margins of the rostrum continued to the tip while the supra-orbital ridges terminate about four-fifths of the way down the rostrum.

With insuficient material available for comparison and study, no positive statement can be made concerning the significance of these features. Should there characters be shown to be consistant in the eastern range of *C. diogenes* a subspecies certainly will be indicated.

Habits.—*Cambarus diogenes* is best known for the chimneys at the entrance of their burrows. These chimneys range from a few inches to as much as a foot in height and the burrows often extend three or more ft below the surface of the soil. The burrow is deep enough to collect water from the water table, run off or seepage and his obvious survival value for the species during the drier months. Many reasons have been offered to explain why these chimneys are constructed, but it seems sufficient to say that *C. diogenes* dig burrows and that the chimneys are a consequence of moving the excavated material out of the hole. The burrows themselves may be quite extensive, consisting of several branches and blind pockets.

Cambarus diogenes is nocturnal in habit. Its burrows, which are usually found in swampy areas or along streams but sometimes in quite firm ground, are made at night. The crayfish remain in the burrows during the day, but often leave them at night when feeding. This species is sometimes encountered a considerable distance from the nearest burrows and, in the spring of the year, even in open water.

Life history.—Ortmann (1906: 480) gives a good account of the life history of this species. The mating season is in August, September, October, and November and the spawning season in April, May, and the beginning of June. Except for a period of about one month in June and July, form I males are present the year round.

Distribution.—There are seven recorded localities for *C. diogenes* in New Jersey, five of which were supplied by Mr. J. Albert Starkey of Vineland. This species is found in the Atlantic

coastal plain south of Trenton and at Schooley's Mountain in Morris County, well within the glaciated area (fig. 8). *Cambarus diogenes* undoubtedly has a wider distribution in New Jersey than is now known.

Ortmann (1906: 459–462) places the origin of this species in southwestern Pennsylvania and northern West Virginia and postulates that it achieved its present range in the east either by descending from the mountains in a northeasterly direction or by being driven back from the north by the advancing ice, along with *Orconectes limosus*. This indicates that the Schooley's Mountain record is either an extension of the migration northward or a remnant of the retreat southward. Both of these theories suffer from a lack of information about the distribution of the species along the proposed migration routes. The author is of the opinion that the Schooley's Mountain record is a fingerlike extension of the northern migration and that *C. diogenes* descended from the mountains in a northeasterly direction to New Jersey. *Orconectes limosus*, which retreated from the north in front of the advancing ice (see distribution of *Orconectes limosus*), is common in southeastern New York and northern New Jersey. If *C. diogenes* had retreated from the north along with *O. limosus*, remnant populations of *C. diogenes* should be found in suitable localities in both New York and New Jersey. Since this species has not been encountered in New York (Crocker, 1957: 90), a northeasterly migration is indicated.

FIGURE 8. Stream map of New Jersey showing locations of collections of *Cambarus diogenes*.

New Jersey Records of Cambarus diogenes

Cape May County

Opposite Bennett's Bog, Bennett. J. A. Starkey. Personal communication.

Cumberland County

Cohansey Creek, Bridgeton, Summer 1951. J. A. Starkey. USNM 92916.
Millville-Milmay Road. J. A. Starkey. Personal communication.
Gravel pit four miles east of Millville. J. A. Starkey. Personal communication.
Near Davis' Mill, seven miles west of Bridgeton, May 25, 1958. J. A. Starkey. DDF 78.

Mercer County

Delaware Meadows near Trenton. Faxon (1885b: 71).
Trenton. Abbott (1873: 83).
Trenton. Fowler (1912: 352).

Morris County

Schooley's Mountain. Fowler (1912: 352).

Delaware River localities from Pennsylvania side

Bucks County

Penns Manor. Ortmann (1906: 405).

Delaware County

Ridley Park, Marcus Hook. Ortmann (1906: 405).

Philadelphia County

Essington. Ortmann (1906: 405).

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LITERATURE CITED

Abbott, C. C. 1873. Notes on the habits of certain crayfish. Amer. Nat. 7: 80–84.
Andrews, E. A. 1904. Breeding habits of crayfish. Amer. Nat. 29: 867–873.
Bouvier, E. L. 1897. Sur les *Cambarus* recueilles au Mexique par M. Bull. Mus. Hist. Nat. (Paris) 3: 224–228.
Cope, E. D. 1872. Report on the Wyandotte Cave and its fauna. Rept. Geol. Surv. Ind. 4: 157–182.
Crocker, D. W. 1957. The crayfishes of New York State. N. Y. State Mus. & Sci. Service Bull. 355: 1–97.
Erichson, W. F. 1846. Uebersicht der Arten der Gattung *Astacus*. Arch. f. Naturgesch. 12(pt 1): 86–103.
Fabricius, J. C. 1798. Supplementum Entomologiae Systematicae. Hofiniae, Proft. et Storch.
Faxon, W. 1884. On the so-called dimorphism in the genus *Cambarus*. Amer. Jour. Sci. 27: 42–44. (Reprinted in Ann. Mag. Nat. Hist. 13: 147–148.)
———. 1885a. Description of new species of *Cambarus*; to which is added a synonymical list of the known species of *Cambarus* and *Astacus*. Proc. Amer. Acad. Arts & Sci. 20: 107–158. Also issued December 1884, "Reprinted from the Proc. Amer. Acad. Arts & Sci., Vol. 20," as Contributions from the Zoological Laboratory of the Museum of Comparative Zoology at Harvard College.
———. 1885b. A revision of the Astacidae. Part I. The genera *Cambarus* and *Astacus*. Mem. Mus. Comp. Zool. 10: 1–186.
———. 1898. Observations on the Astacidae in the United States National Museum and in the Museum of Comparative Zoology, with descriptions of new species. Proc. U. S. Nat. Mus. 20: 643–694.

———. 1914. Notes on the crayfishes in the United States National Museum and the Museum of Comparative Zoology, with descriptions of new species and subspecies, to which is appended a catalog of known species and subspecies. Mem. Mus. Comp. Zool., Harvard College 40: 351–427.

Fowler, H. W. 1912. The Crustacea of New Jersey. Ann. Rept. N. J. State Mus. for 1911 (pt 2): 31–650.

Girard, C. 1852. A revision of the North American Astaci, with observations on their habits and geographical distribution. Proc. Acad. Nat. Sci. Phila. 6: 87–91.

Hagan, H. A. 1870. Monograph of the North American Astacidae. Illus. Cat. Mus. Comp. Zool., Harvard College: 1–109.

Harlan, R. 1830. Description of a new species of the genus *Astacus*. Trans. Amer. Philos. Soc. Phila. 3: 464–465.

Hobbs, H. H. 1942a. A generic revision of the crayfishes of the subfamily Cambarinae with the description of a new genus and species. Amer. Midl. Nat. 28: 334–357.

———. 1942b. The crayfishes of Florida. Univ. Fla. Publ., Biol. Sci. Ser. 3: 1–179.

Milne-Edwards, H. 1837. Histoire naturelle des crustacées. Paris.

Ortmann, A. E. 1905a. The mutual affinities of the species of the genus *Cambarus*, and their dispersal over the United States. Proc. Amer. Philos. Soc. 44: 91–136.

———. 1905b. *Procambarus*, a new subgenus of the genus *Cambarus*. Ann. Carnegie Mus. (Pittsburgh) 3: 335–442.

———. 1905c. The crawfishes of western Pennsylvania. Ann. Carnegie Mus. (Pittsburgh) 3: 387–406.

———. 1906. The crawfishes of the state of Pennsylvania. Mem. Carnegie Mus. (Pittsburgh) 2: 343–533.

Osborn, R. C. and **E. B. Williamson.** 1898. The crayfish of Ohio. Sixth Ann. Rept. Ohio State Acad. Sci. 21.

Rafinesque, C. A. 1817. Synopsis of four new genera and ten new species of Crustacea found in the United States. Amer. Monthly Mag. & Crit. Rev. 2: 40–43.

Say, T. 1817. An account of the Crustacea of the United States. Jour. Acad. Nat. Sci. Phila. 1 (pt 1): 155–169, 235–253, 316–319, 374–401, 423–451.